



A relocatable lander to explore Titan's  
prebiotic chemistry and habitability

# The Dragonfly Entry and Descent System

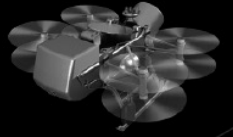
Presentation – UTSI Knoxville

March 1, 2022

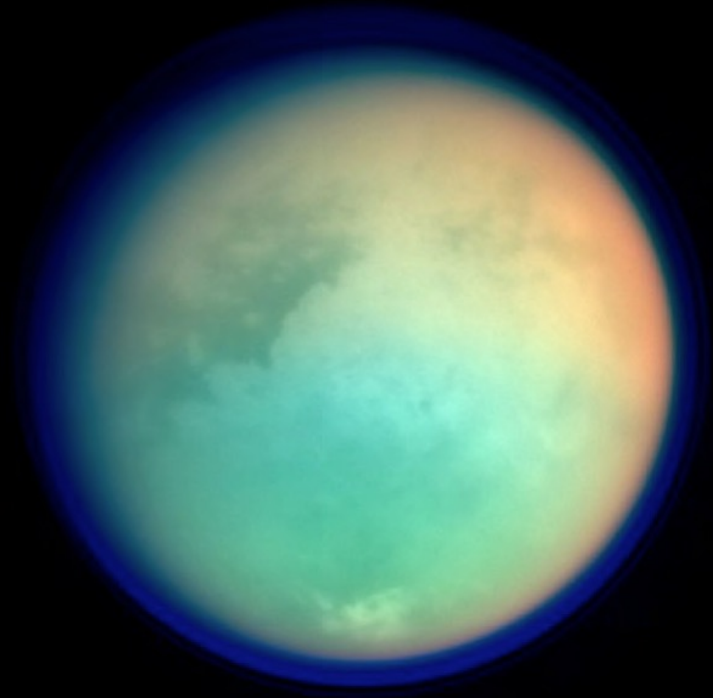
Michael Wright (Dragonfly EDL Phase Lead)

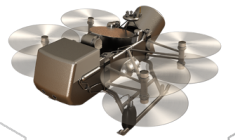


# Titan : Largest of Saturn's Moons



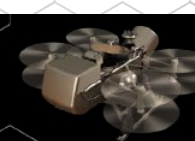
- Diameter = 5150 km
- Surface gravity =  $1.35 \text{ m/s}^2 = 0.14 \text{ g}$ 
  - 14% of gravity at Earth's surface
  - 83% of gravity at Moon's surface
- Surface pressure = 1.5 bar
  - 1.5× pressure at Earth's surface (4× density)
- Surface temperature =  $94 \text{ K} = -290^\circ\text{F}$ 
  - Bedrock composition = water ice
  - Atmospheric composition = nitrogen, few % methane





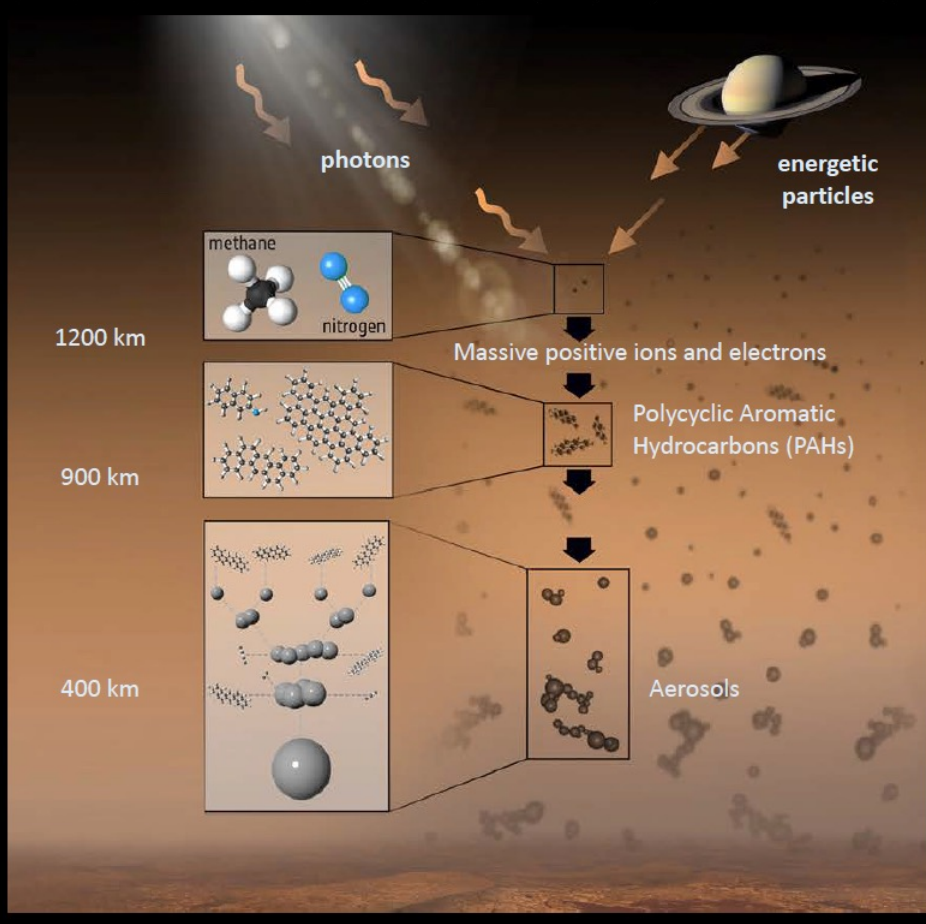
# Why Titan?

# Complex organic chemistry

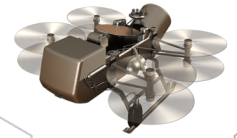
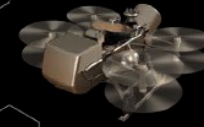


- Titan's unique atmosphere supports rich photochemistry
- Organic material produced in the atmosphere covers the surface
- Potential for organic compounds to have mixed with liquid water
- Materials are easily accessible on the surface

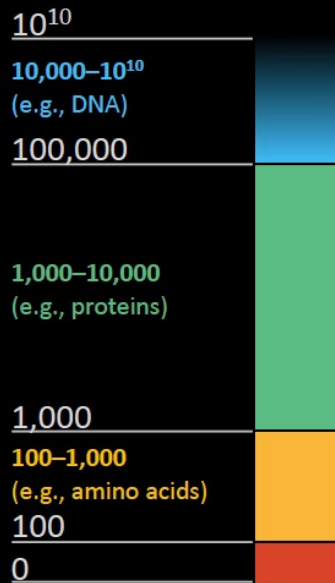
Titan is a singular destination for understanding the chemical processes on our own planet that supported the development of life



# Titan's organic complexity approaches that on Earth



**Molecular Complexity**  
(amu)



TITAN



SATURN



ENCELADUS



EARTH



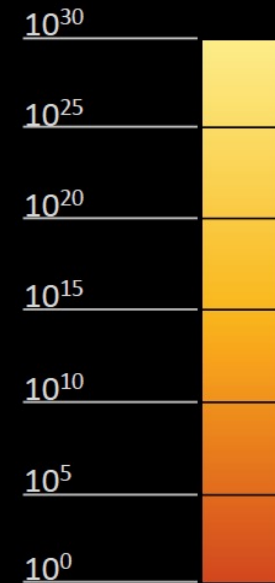
MARS



VENUS



**Carbon Abundance**  
(GT)

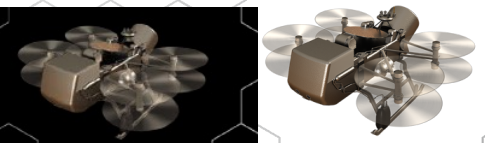




# Why a Relocatable Lander?

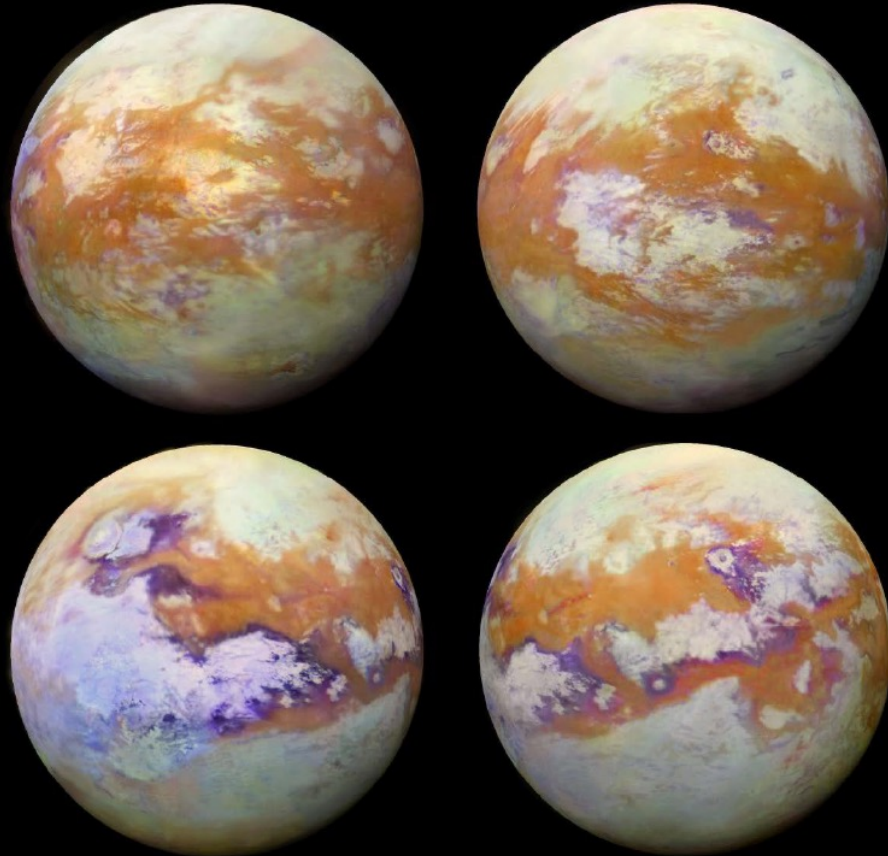


## *Cassini-Huygens* has revealed where to look for answers

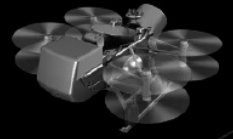


- Diverse surface materials and environments
- Earth-like variety of geologic processes
- Science challenge is to get instruments to multiple high-priority sites to sample materials and measure compositions

Mobility is key for science measurements



# Lander with aerial mobility enables wide-ranging in situ exploration – key for science measurements

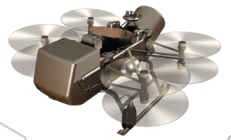


- Heavier-than-air mobility highly efficient at Titan
  - Atmospheric density 4x higher than Earth's reduces wing/rotor area required for lift
  - Gravity 1/7th Earth's → reduces power required





## A Note on Scale



### Ingenuity



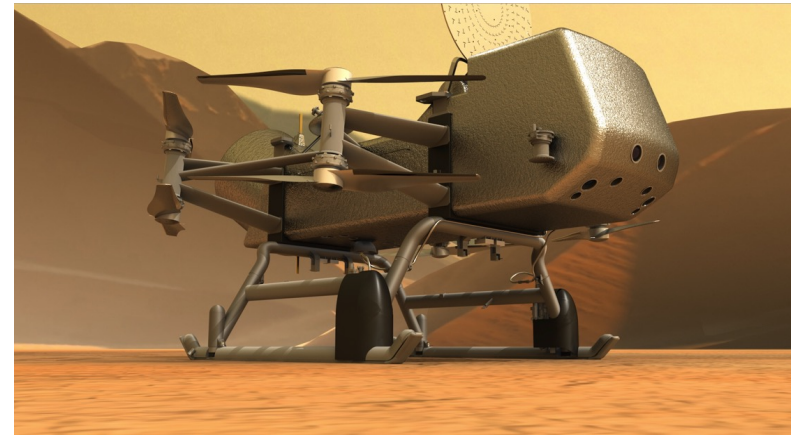
#### Key Dimensions:

Fuselage: 13.6x19.5x16.3 cm

Rotor Diameter: 1.2 m

Total Mass: 1.8 kg

### Dragonfly



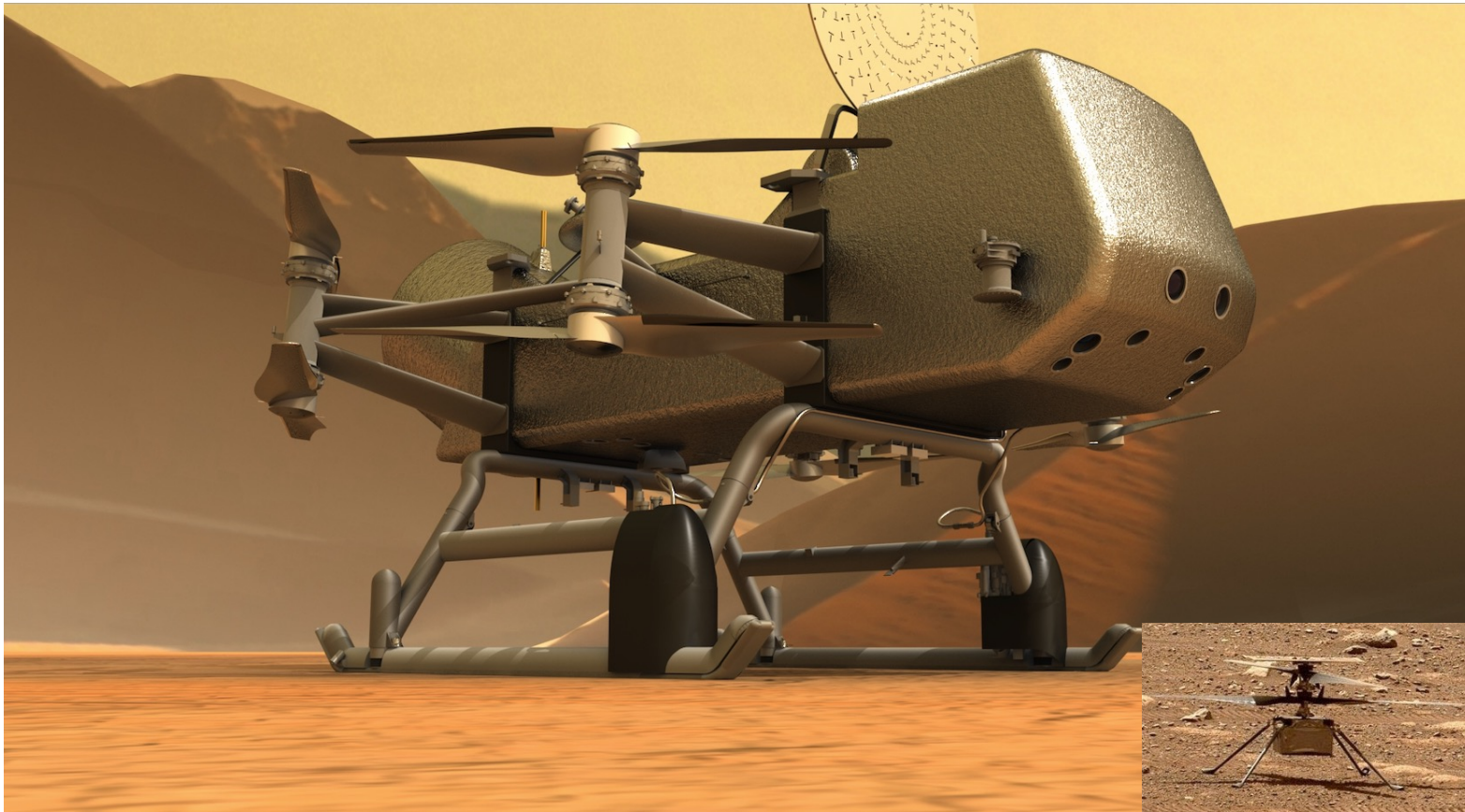
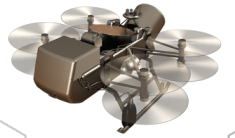
#### Key Dimensions:

Fuselage: ~3.85 m long

Rotor Diameter: ~1.35 m

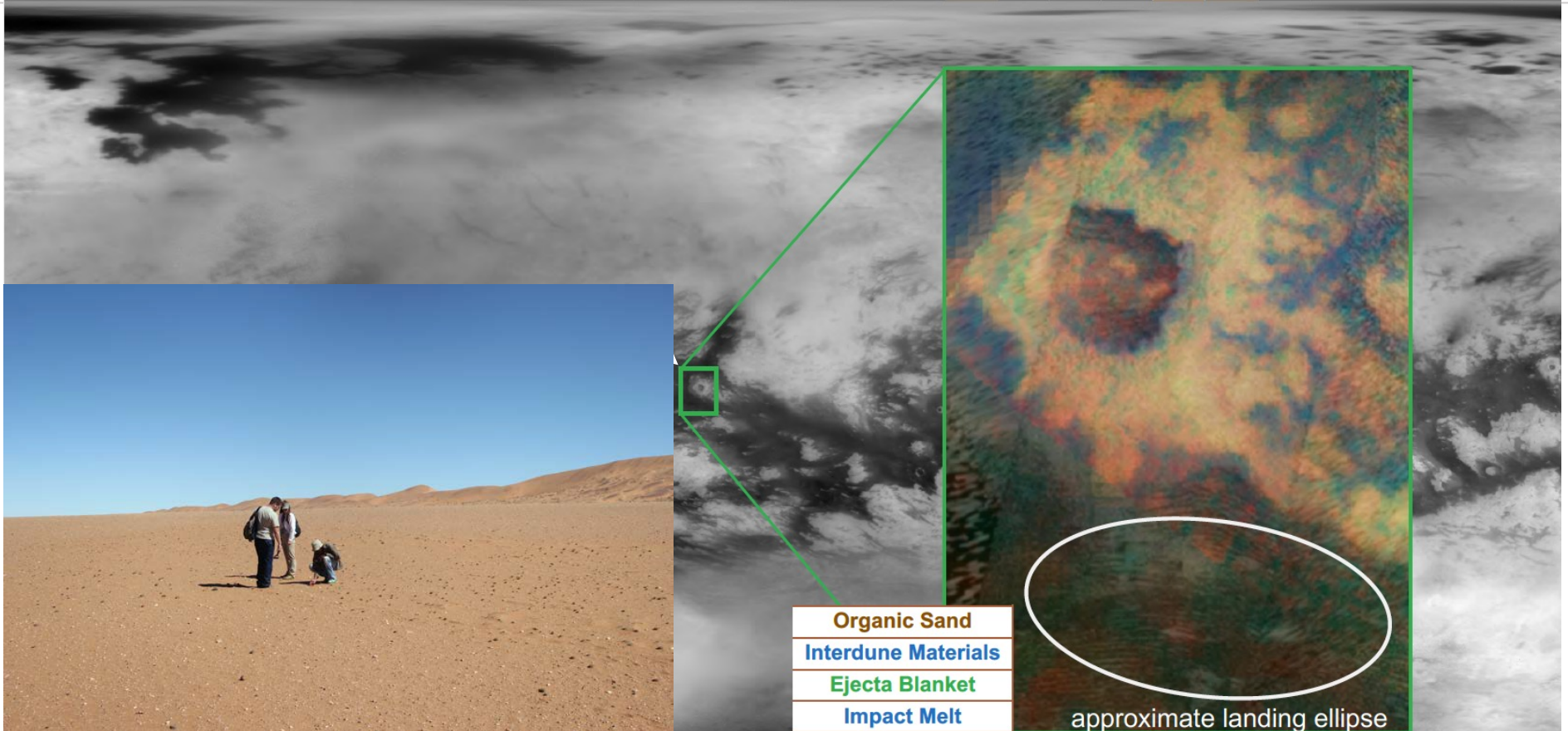
Total Mass: ~900 kg

## A Note on Scale

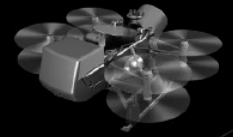




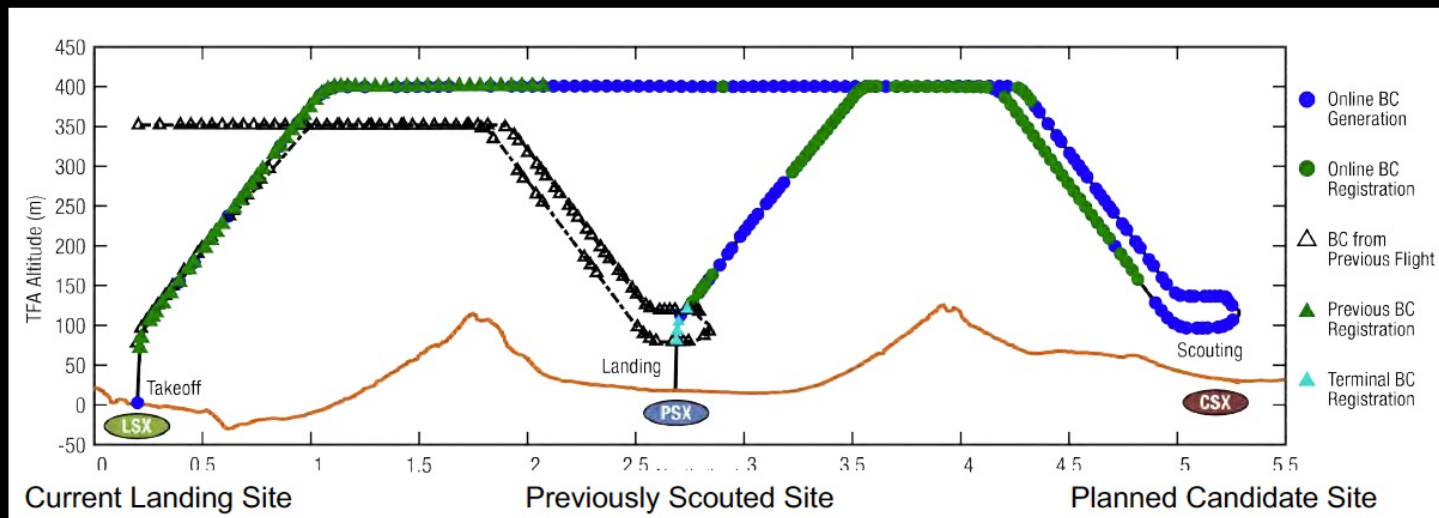
# Organic sediments and materials with a water-ice component: dunes, interdunes, impact crater deposits

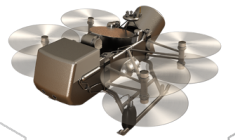


# Dragonfly exploration strategy



- “Leapfrog” exploration strategy to scout future landing sites
- 16-day Titan sols → relaxed operations schedule
  - Nominal flight schedule is once per 2 Tsols (~1 flight / Earth month)
  - Most of time is spent on the surface making science measurements

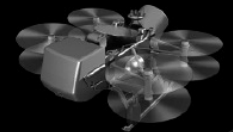




# How Will We Get it There?



# Dragonfly mission elements



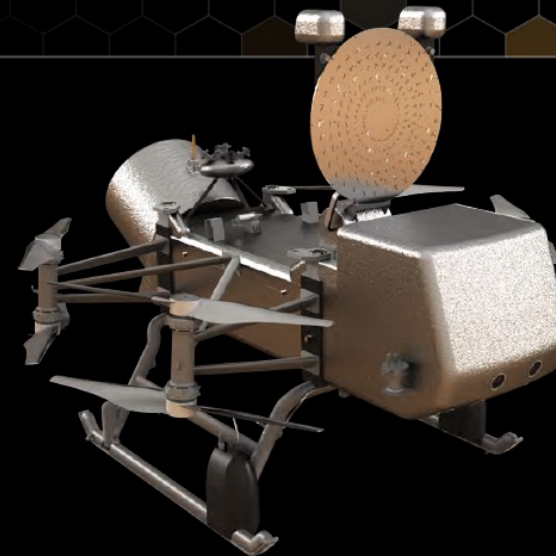
**Spacecraft =  
Cruise Stage + Entry Vehicle**



**Entry Vehicle =  
EDL Assembly + Lander**



*EDL assembly  
includes aeroshell  
(heatshield and  
backshell),  
parachutes, ESI, and  
support equipment.*



**Rotorcraft Lander**  
*Surface configuration  
with HGA deployed*

## MMRTG

- Charges battery to power flight and science activities
- Waste heat maintains nominal thermal environment in lander

## Direct-to-Earth communication

- HGA articulation used to target cameras for panoramas of surrounding terrain

## Measurements on surface and in flight

- Aerial imaging
- Atmospheric profiles

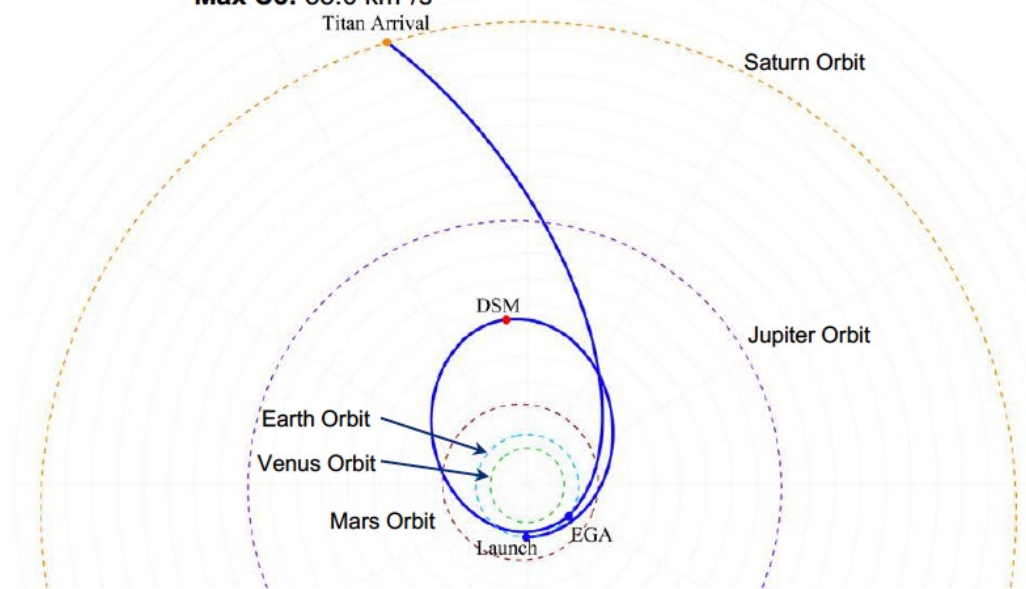
# Interplanetary trajectory



## 2027 $\Delta V$ -EGA

Launch Period: 6/20/2027 – 7/10/2028 (21 days)

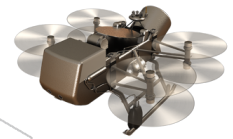
Max C3:  $55.0 \text{ km}^2/\text{s}^2$



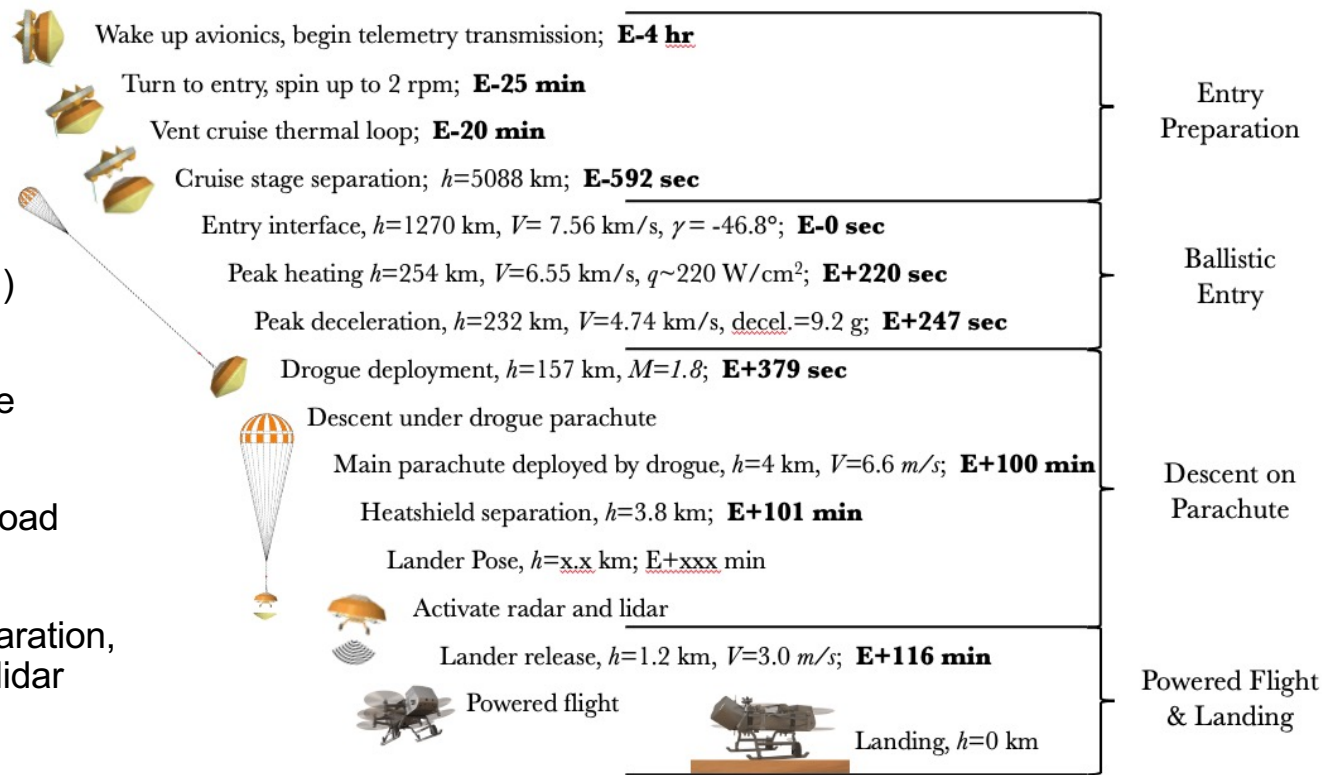
launch period



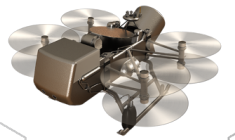
# EDL Concept of Operations



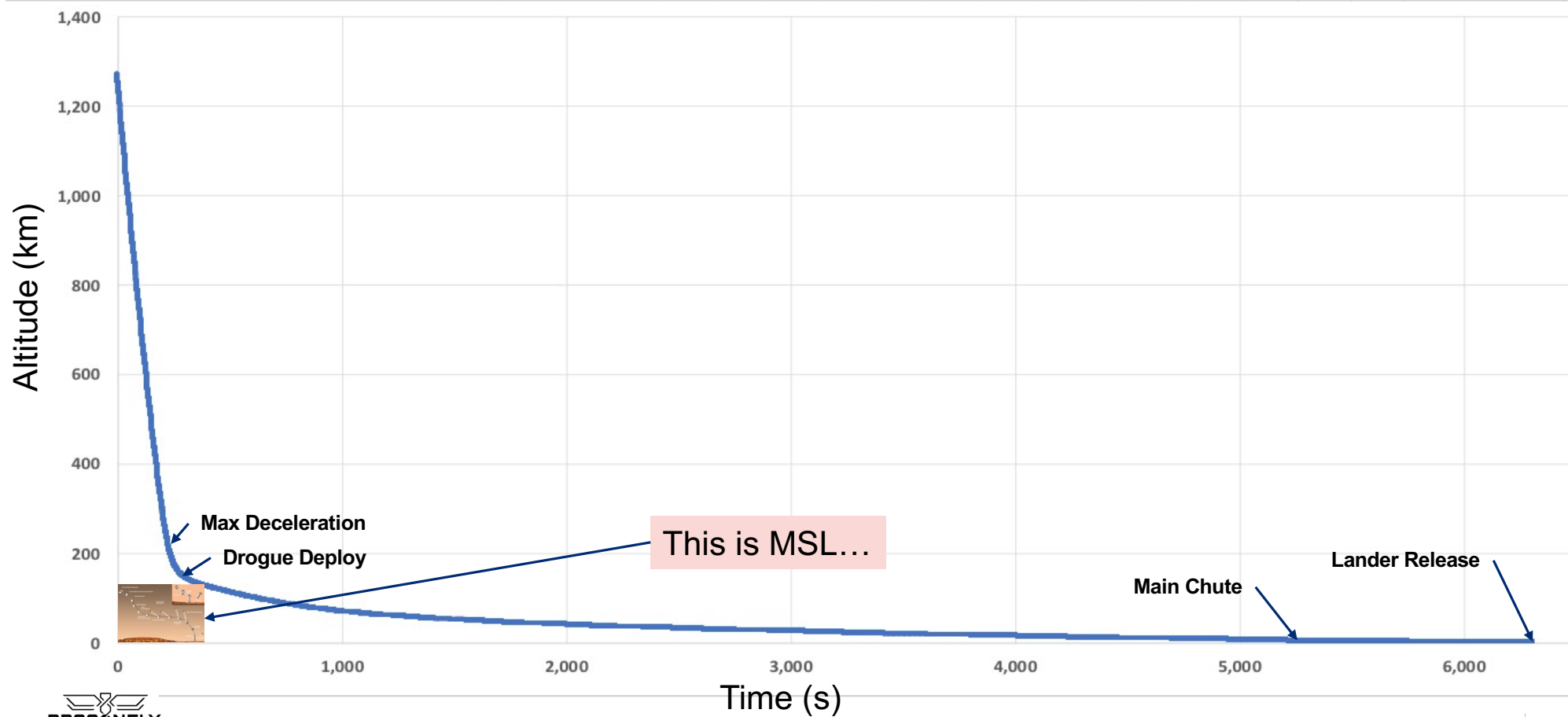
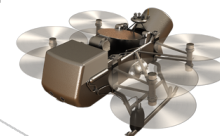
- Entry Interface 1270 km
  - Spin-stabilized to 2 rpm
- Entry heat pulse: 260 sec.
  - Peak heat flux  $>250 \text{ W/cm}^2$  (margined)
- Drogue deploy E+6 min,  $\sim$ Mach 1.5.
  - More than 90 minutes spent on drogue
- Main chute deploy E+100 min.
  - Low velocity (6.6 m/s) & low opening load
- Lander Release E+116 min.
  - Plenty of time to stage heatshield separation, pose the lander, and activate radar & lidar



## EDL Video

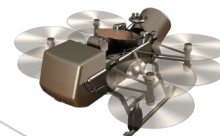


# EDL Timeline Comparison

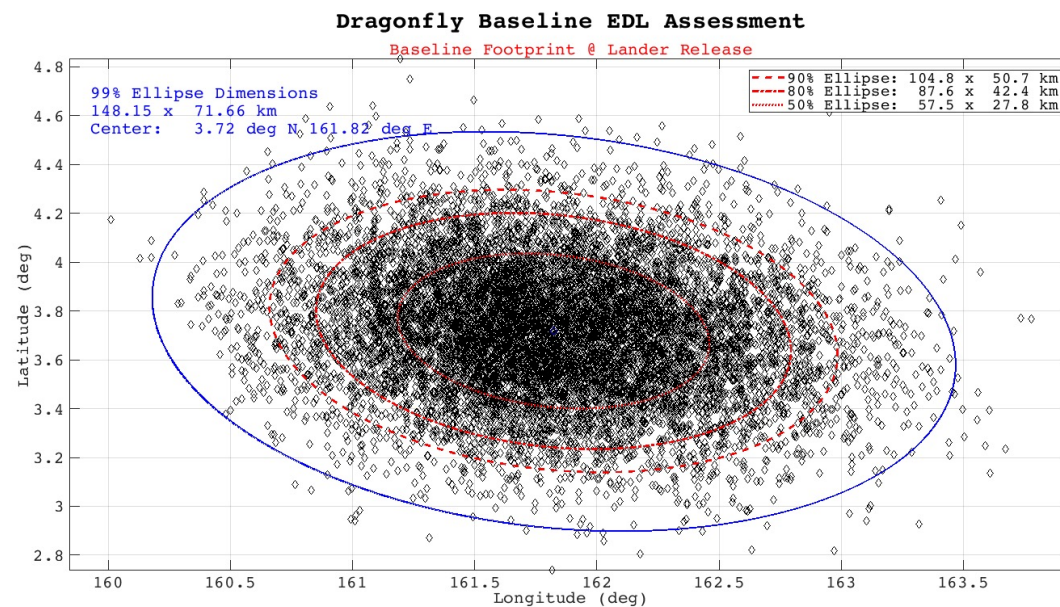




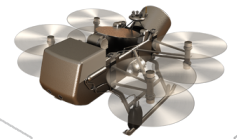
# EDL Monte Carlo Analysis



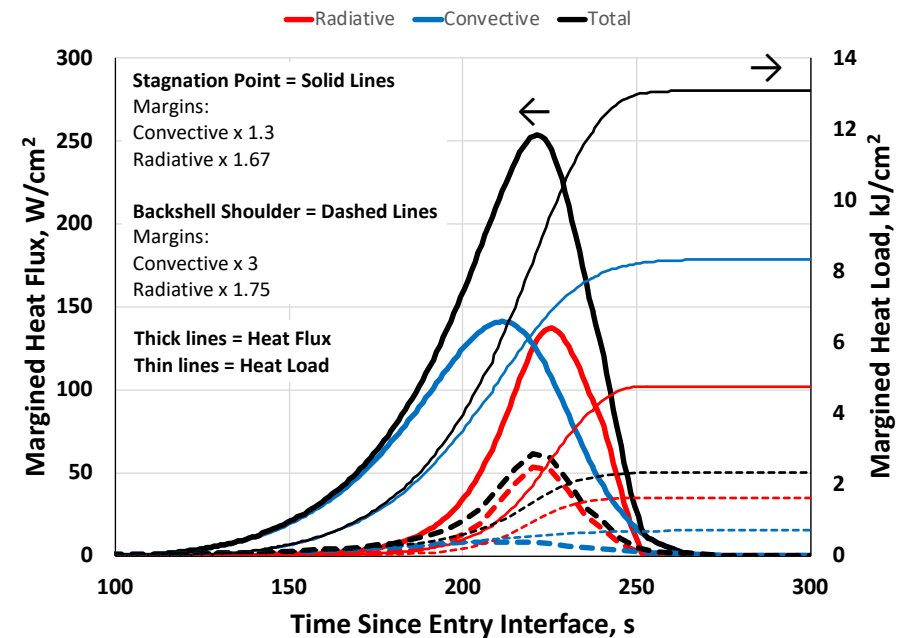
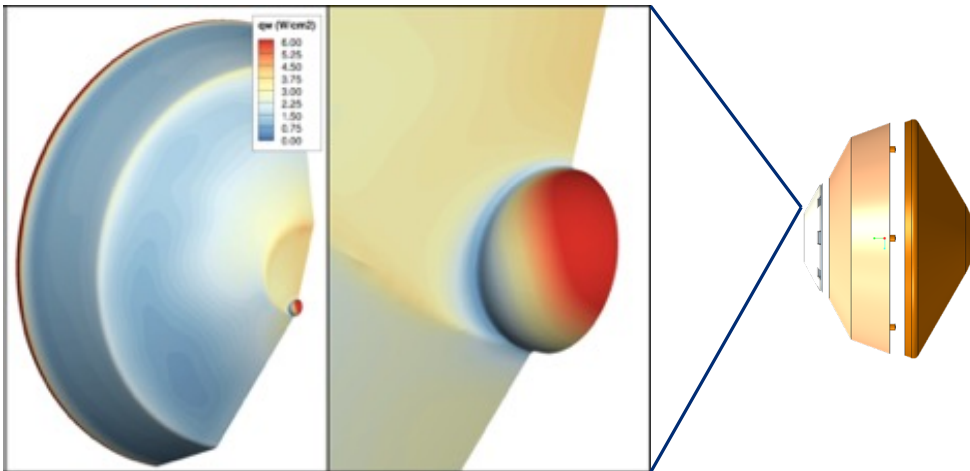
- Full analysis in POST2 from entry interface to lander release
- Delivery accuracy ~149x72 km at release
  - Affords lander sufficient accuracy to navigate to selected landing zone
- Dispersions sources
  - Latitude: arrival navigation errors
  - Longitude: on-chute winds



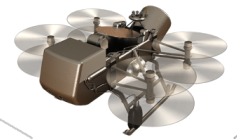
# Aerothermodynamics



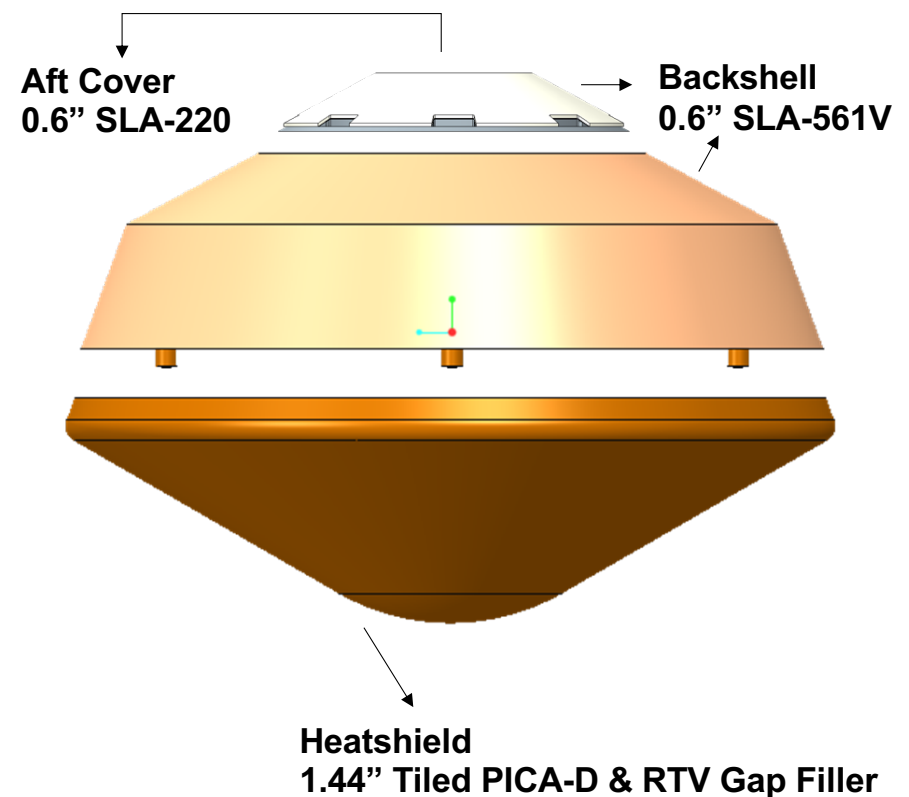
- NASA standard aerothermal models tuned for Titan entry conditions
  - Much of the heating comes from radiation due to methane
- Total heating calculated over entire aeroshell
  - Conservative margins applied
  - Margined values within tested limits for chosen TPS



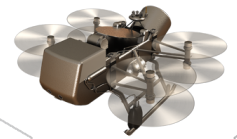
# Thermal Protection System



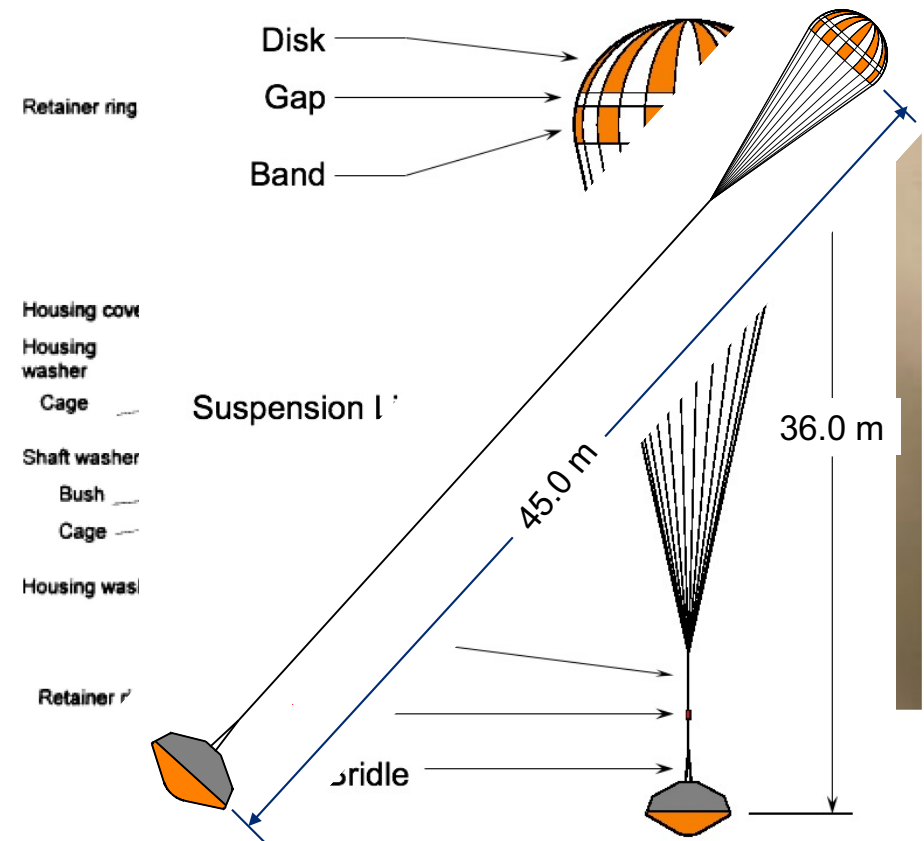
- Three TPS materials:
  - High TRL and used well within tested limits
  - Arc jet testing confirms performance
  - SMD funded PICA-D is a drop-in replacement for heritage PICA; fabrication of DF billets will start this year
- TPS sizing & margin analysis uses mature processes developed during MSL/Orion
  - Design thicknesses carry unallocated margin
- TPS manufacture, testing, qualification and assembly follow standard procedures developed at LM and NASA ARC



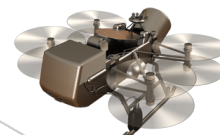
# Parachute Deceleration System



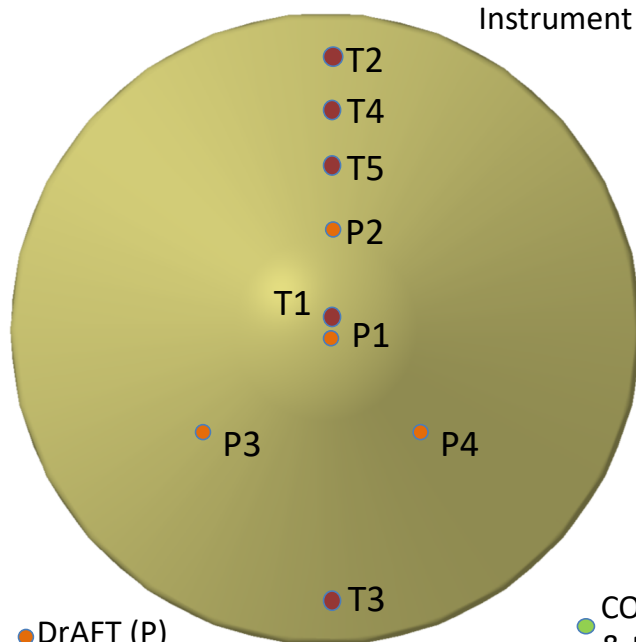
- Drogue Parachute (5.4 m DGB)
  - Mortar deploy via trigger at Mach 1.5
  - Functions: stabilize capsule, decelerate through atmosphere, extract main chute
- Main Parachute (13.44 m DGB)
  - Low speed subsonic deploy
  - Possible anti-inversion netting
- Huygens heritage swivels prevent line twisting



# DrEAM: Preliminary Sensor Layout

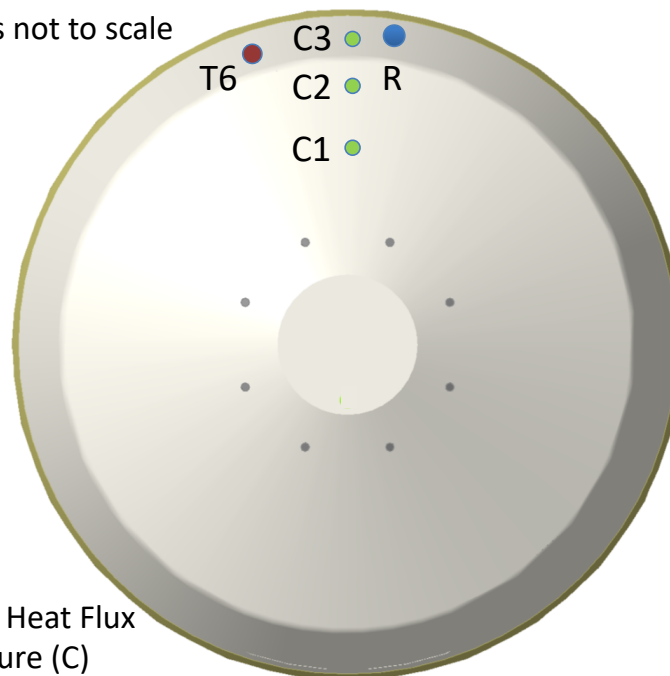


Instrument plugs not to scale



● DrAFT (P)  
● DragSTR (T)

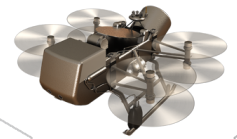
● COSSTA Heat Flux  
& Pressure (C)  
● COSSTA  
Radiometer (R)  
● DragSTR (T)



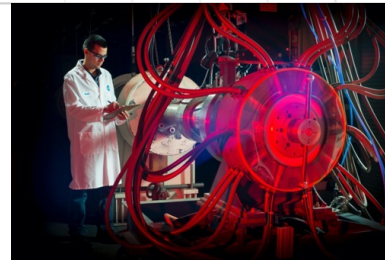
- Dragonfly Sensors for Thermal Reconstruction (DragSTR):
  - 5 forebody TC plugs, 1 aftbody TC plug
- Dragonfly Atmospheric Flight Transducers (DrAFT):
  - 4 forebody pressure transducers
- COmBined Sensor System for Titan Atmosphere (COSSTA):
  - 3 combined total heat flux, pressure and temperature sensors
  - 1 radiometer



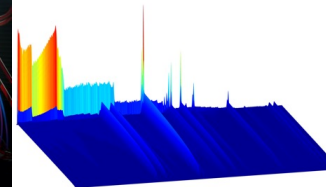
# Key EDL Challenges (time sequence order)



- **Quantifying heating due to shock layer radiation**
  - dominated by CN-red and violet emission
  - Less validated than air or CO2
- **TPS material qualification**
  - Non-oxidizing environment, radiation dominated heating
- **EDL Phase thermal analysis**
  - Long descent time, cryogenic exterior, internal heat source
- **Transonic-subsonic aerodynamics**
  - Drogue chute is relatively smaller than that for Genesis
  - Initial analysis shows that capsule dynamics dominates system dynamics
  - Heritage ADB is not high fidelity in this speed regime
- **Very long inflation time and possible high angle of attack at deploy for main chute**
  - Anti-inversion netting baselined
  - Drop testing is planned



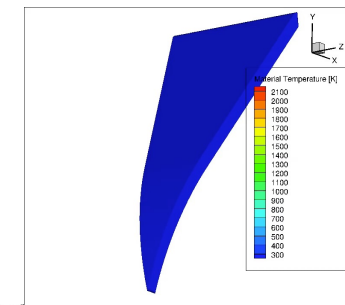
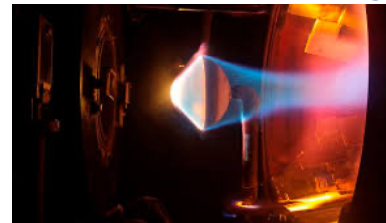
**EAST Testing\***



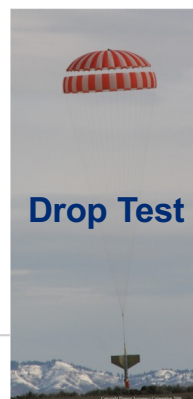
**VST/TDT Testing**



**Arc Jet / Lamp Testing**

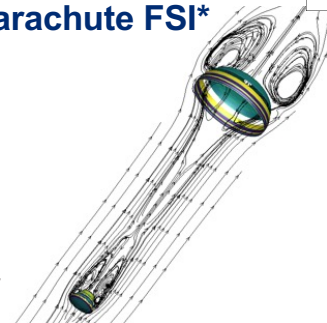


**3D Material Response\***

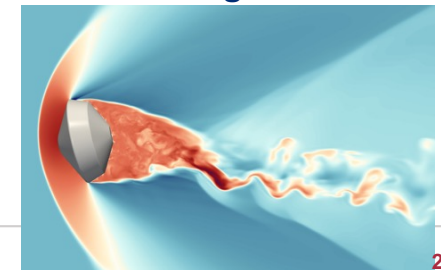


**Drop Test**

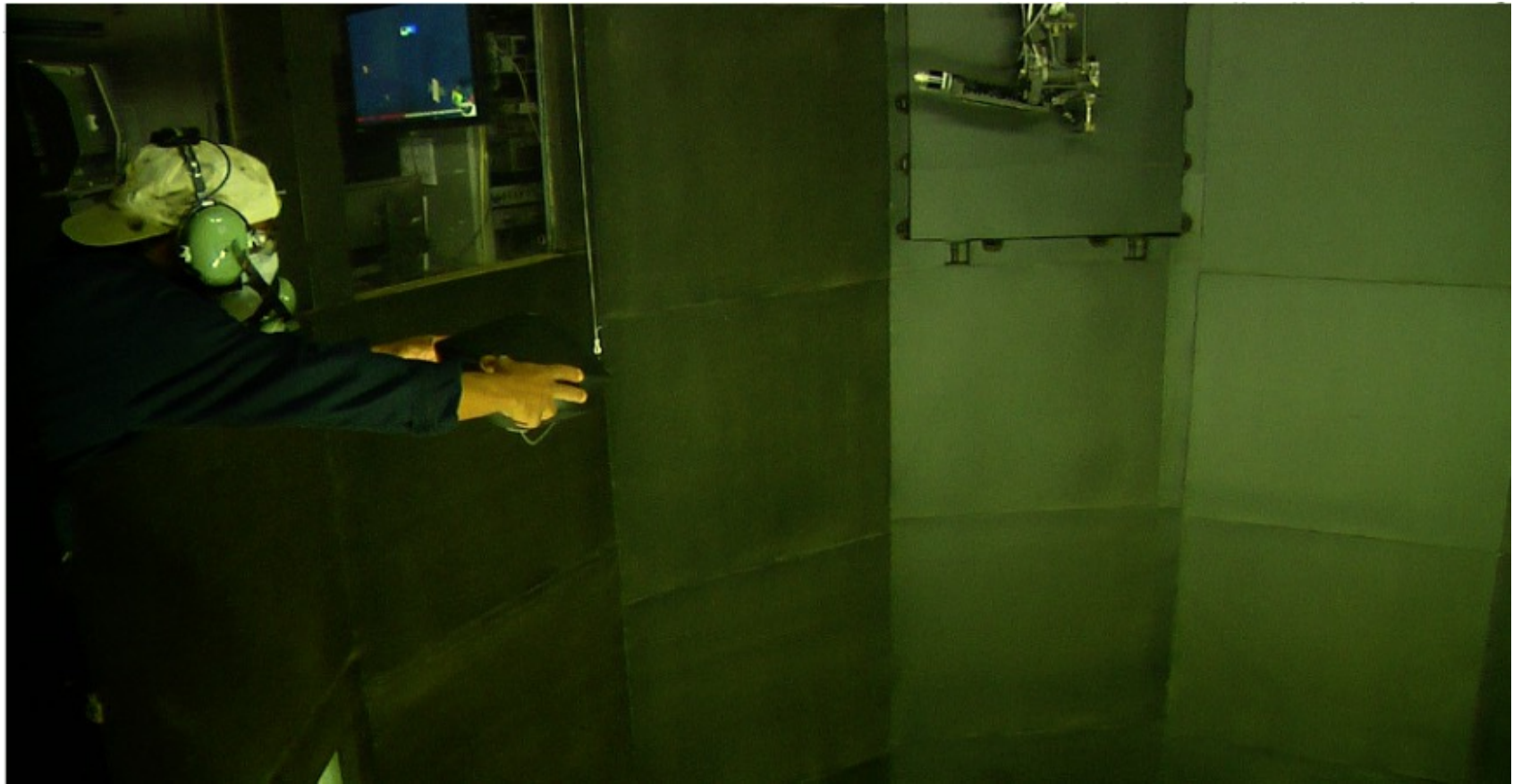
**Parachute FSI\***



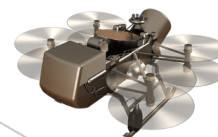
**Free Flight CFD\***



# Vertical Spin Testing – Drogue Chute Dynamics







# Backup